

11-24-00

11/22/00
JC957 U.S. PTO

IN THE UNITED STATES PATENT AND TRADEMARK

Box New Patent Application
Assistant Commissioner for Patents
Washington, D.C. 20231

Attorney's Docket No.: SJO990197US1

JC957 U.S. PTO
09/721264
11/22/00

FILING TRANSMITTAL

Transmitted herewith for filing is the Patent Application of : Pocker et al.

For: **"ENERGY GRADIENT ION BEAM DEPOSITION OF CARBON OVERCOATS
ON RIGID DISK MEDIA FOR MAGNETIC RECORDINGS"**

ENCLOSURES

- ☒ 19 page application including specification, claims and abstract;
 - ☒ 2 sheets (Figs. 1 - 6) of ☒ informal/☐ formal drawings;
 - ☒ A Declaration, Power of Attorney & Petition (☐ signed/☐ unsigned);
 - ☒ A postcard for return to us as proof of receipt of the referenced documents.
- and**
- ☒ An Assignment of the invention with an assignment cover sheet;
 - ☐ Verified Statement Claiming Small Entity Status (37 CFR 1.9(f) and 1.27(b));
 - ☒ IDS (form PTO-1449) and copies of references;
 - ☐ An Associate Power of Attorney;
 - ☐ A certified copy of the priority document (Under 35 USC 119);
 - ☐ A Power of Attorney by Assignee;
 - ☐ Other.

TYPE OF FILING

- ☐ This application claims the benefit of an earlier filed U.S. Patent Application (35 USC 120).
- ☐ This application claims the benefit of the priority date of an earlier filed provisional patent application (35 USC 119).
- ☐ This is an application filed pursuant to 37 CFR 1.53, permitting receipt of a filing date upon filing of specification, claims and drawings, if required, with applicant being given a period of one month from the date of notice to file the fee and oath or declaration.
- ☒ In the event any parts of this application are missing, please treat this as a filing under 37 CFR 1.53 as defined just above.

CERTIFICATE OF MAILING (37 CFR 1.10(A))

CERTIFICATE OF MAILING BY "EXPRESS MAIL" - Rule 10: I hereby certify that this correspondence is being deposited with the U. S. Postal Service "Express Mail Post Office to Addressee" under 37 CFR 1.10 as Express Mail No. EL654882455US addressed to the Assistant Commissioner for Patents, Washington, D.C. 20231 on November 21, 2000 by Patricia Beilmann.

Date: November 21, 2000

Patricia Beilmann
Patricia Beilmann

FEE CALCULATION

The filing fee has been calculated as shown below:

				SMALL ENTITY	OR	OTHER THAN A SMALL ENTITY	
BASIC FEE Design Patent				\$160	\$	\$320	\$
BASIC FEE Utility Patent				\$355	\$	\$710	\$710
EXTRA FEES				RATE	FEE	RATE	FEE
Total claims	26	minus 20 =	6	x9 =	\$0	x18 =	\$108
Independent Claims	4	minus 3 =	1	x40 =	\$0	x80 =	\$80
<input type="checkbox"/> Multiple Dep. Claim				+130 =	\$	+260 =	\$
<input checked="" type="checkbox"/> Assignment				+40 =	\$	+40 =	\$40
<input type="checkbox"/> Rule 53 Surcharge				+65 =	\$	+130 =	\$
TOTAL					\$		\$938

FEE PAYMENT

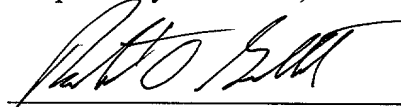
- ☒ Attached is Check No. 124677 in the sum of \$938.00 to cover the filing fee.
☐ Please charge Account No. 02-3964 the sum of \$_____

FEE DEFICIENCY

- ☐ Please charge Account No. 02-3964 in the sum of \$_____
- ☐ The Commissioner is authorized to charge (or credit any overpayment) to deposit account No. 02-3964:
- ☐ Any additional filing fees required under 37 CFR 1.16, except Rule 53 filings, which will be paid within the time permitted by PTOL 1533.
 - ☐ Assignment Recordal fees.
- ☒ The filing fee and surcharge under 37 CFR 1.16, patent application processing fees under 37 CFR 1.17 and patent issue fees under 37 CFR 1.18 are intended to be paid by our firm as they arise. As no abandonment is intended by any inadvertent nonpayment of fees, the Commissioner is hereby authorized to charge payment of such fees as from time to time come due, if not paid prior to due date to our Deposit Account No. 02-3964.
- ☐ A duplicate copy of this sheet is enclosed.

Dated: November 21, 2000

Respectfully submitted,



ROBERT O. GUILLOT

Reg. No: 28,852

OPPENHEIMER WOLFF & DONNELLY LLP
Customer No. 25696
1400 Page Mill Road
Palo Alto, CA 94304
Tel: (650) 320-4000

Specification

ENERGY GRADIENT ION BEAM DEPOSITION OF CARBON OVERCOATS ON RIGID DISK MEDIA FOR MAGNETIC RECORDINGS

BACKGROUND OF THE INVENTION

5 Field of the Invention:

The present invention relates generally to protective layers fabricated upon magnetic layers of hard disk media, and more particularly to thin film diamond-like carbon protective layers.

Description of the Prior Art:

10 Standard magnetic media hard disks include a magnetic layer that is covered by a protective overcoat layer. The overcoat layer is necessary to provide both mechanical and corrosion protection for the magnetic layer, and typical prior art overcoat layers are composed of a hard, carbon based composition that is applied by a magnetron sputtering technique to a thickness of approximately 50 to 200 Å.

15 The ongoing efforts to increase the areal data storage density of magnetic disks have resulted in a need to reduce the thickness of the overcoat layer while increasing the hardness, or density of the overcoat layer. It has been found that a typical magnetron sputtered overcoat of below approximately 50 Å is not sufficiently hard, nor does it provide sufficient corrosion protection to the magnetic layer, due to the generally low energy (approximately 10 eV) at which
20 the carbon atoms are deposited. Efforts to create a thin, hard, corrosion resistant overcoat have therefore been directed towards fabrication devices such as mass selected ion beam deposition (MSIB), cathodic arc, laser plasma deposition and plasma enhanced chemical vapor deposition

(PECVD) which produce carbon atom deposition energies of 100 eV or more. While such 100 eV deposited overcoat layers provide good mechanical and corrosion resistance properties, they also create deterioration problems for the underlying magnetic layer. Specifically, at such high energies, the carbon atoms, as well as other atoms such as nitrogen and hydrogen that are often
5 utilized in forming the overcoat layer, become implanted into the magnetic layer to a significant depth. The implanted atoms can seriously degrade the magnetic properties of the magnetic layer within its upper regions, thus resulting in degraded performance of a magnetic disk that is fabricated with an overcoat layer formed with prior art high energy carbon deposition techniques.

The present invention solves these prior art problems through the use of an energy
10 gradient ion beam deposition technique in which the implanting of carbon overcoat ions into the magnetic layer is reduced.

SUMMARY OF THE INVENTION

In the energy gradient ion beam deposition technique of the present invention, the fabrication of the overcoat layer starts with a low energy ion beam to avoid magnetic layer
15 implantation problems, followed by higher deposition energies where the higher energy atoms are implanted into the previously formed lower energy overcoat layer, rather than the magnetic layer. The energy gradient ion beam deposition process therefore results in a thin overcoat layer that is denser than a comparable layer formed by low energy magnetron sputtering, and which overcoat layer provides good mechanical and corrosion protection to the magnetic layer, without
20 degrading the magnetic properties of the magnetic layer. Where a magnetic media hard disk of the present invention is utilized within a hard disk drive, the thinner overcoat layer allows the magnetic head of the disk drive to fly closer to the magnetic media layer, thereby facilitating an increase in the areal data storage density of the hard disk drive.

It is an advantage of the magnetic media hard disk of the present invention that it is fabricated with a thinner overcoat layer.

It is another advantage of the magnetic media hard disk of the present invention that it is fabricated with a denser overcoat layer.

5 It is a further advantage of the magnetic media hard disk of the present invention that it is fabricated with a thinner, denser effective overcoat layer wherein minimal implantation of carbon ions into the magnetic media layer is found.

It is yet another advantage of the magnetic media hard disk of the present invention that it is fabricated with a thinner effective overcoat layer such that a greater areal data storage density
10 can be created with said disk.

It is an advantage of the magnetic media hard disk drive of the present invention that it includes one or more magnetic media hard disks of the present invention wherein the data storage within said disk drive is increased.

It is another advantage of the hard disk drive of the present invention that it includes one
15 or more magnetic disks of the present invention having a thinner effective overcoat layer, such that the areal data storage density of said hard disk drive may be increased.

It is an advantage of the fabrication process for a magnetic media hard disk of the present invention that a thinner, denser overcoat layer is fabricated with minimal carbon ion implantation into a magnetic media layer of the hard disk.

20 It is another advantage of the fabrication process for a magnetic media hard disk of the present invention that controlled deposition of nitrogen ion species into the overcoat layer may be accomplished.

These and other features and advantages of the present invention will no doubt become apparent to those skilled in the art upon reading the following detailed description which makes reference to the several figures of the drawings.

IN THE DRAWINGS

5 Fig. 1 is a side cross-sectional view depicting a prior art overcoat layer formed by magnetron sputtering fabrication techniques;

Fig. 2 is a side cross-sectional view of a prior art magnetic disk including an overcoat layer that is formed utilizing high energy carbon ion beam fabrication techniques;

10 Fig. 3 is a graphical representation of the implantation of carbon ions of various energy levels into a magnetic layer;

Fig. 4 is a side cross-sectional view depicting a magnetic disk having an overcoat layer that is fabricated utilizing the energy gradient ion beam deposition technique of the present invention;

15 Fig. 5 is a graphical representation of the implantation of 100 eV carbon ions into 20 Å carbon surface layers having different densities; and

Fig. 6 is a schematic top plan view of a hard disk drive including the magnetic disk of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

20 As is well known to those skilled in the art, a thin film overcoat layer is fabricated upon the magnetic layer of a magnetic media hard disk to provide mechanical and corrosion protection to the magnetic layer. Fig. 1 is a side cross-sectional view of a typical prior art magnetic media hard disk 10 having such an overcoat. As depicted in Fig. 1, the prior art hard disk 10 includes a disk substrate 14 that typically has a plurality of thin film layers deposited thereon. While

various types of prior art hard disks exist, with various numbers and compositions of thin film layers, for the purposes of this disclosure, a typical prior art hard disk 10 can be said to include a at least one underlayer 18 formed upon the surface of the substrate 14, a magnetic layer 26 formed upon the underlayer 18, and an overcoat layer 30 formed upon the magnetic layer 26. As indicated above, the present invention is directed to the features and relationships between the magnetic layer 26 and the overcoat layer 30. In a typical prior art hard disk 10, the magnetic layer 26 is composed of a magnetic material, usually having a CoPtCr composition, that has a thickness of approximately 50 to 200 Å. The overcoat layer 30 is composed of diamond-like carbon (DLC) and is applied utilizing a magnetron sputtering technique having a relatively low application energy that is less than or equal to approximately 10 eV, and the DLC layer 30 is deposited to a thickness of at least approximately 50 Å to 200 Å. It is significant that there is very little implantation of the sputtered carbon ions of the overcoat layer 30 into the magnetic layer 26, due to the low ion energy level of the overcoat layer fabrication technique.

To increase the hard disk data areal storage density, it is desirable to write magnetic data bits closer together in the data track; that is, to increase the number of bits per inch (BPI). To accomplish this, it is desirable to have the magnetic write head positioned closer to the magnetic layer, and decreasing the thickness of the overcoat layer 30 is advantageous in this regard. However, it has been found that if the thickness of the prior art low energy magnetron sputtered overcoat layer 30 is reduced to below approximately 50 Å, both the mechanical protection and corrosion protection of the magnetic layer is adversely affected. A prior art approach to resolve this problem is to apply the overcoat layer 30 utilizing a higher energy ion beam fabrication technique, such that a denser overcoat layer is fabricated than is achieved in the low energy magnetron sputtering process. Where the overcoat layer is denser, a thinner layer will

provide suitable mechanical and corrosion protection to the magnetic layer, and a magnetic hard disk 50 with such a prior art high deposition energy DLC overcoat layer is depicted in Fig. 2.

As depicted in Fig. 2, the prior art magnetic hard disk 50 includes a substrate 14 upon which an underlayer 18 has been deposited, followed by a 200 Å thick magnetic layer 26. The layers 14, 18 and 26 may be identical to those described above with regard to prior art hard disk 10, whereby identical identification numbers are used herein. A DLC overcoat layer 54 that is fabricated in a high energy fabrication process such as mass selected ion beam deposition (MSIB), cathodic arc, laser plasma deposition and plasma enhanced chemical vapor deposition (PECVD) is formed upon the magnetic layer 26. It has been observed that some of the high energy carbon ions that form the overcoat layer 54 penetrate into the magnetic layer 26, forming an ion implanted upper portion 58 of the magnetic layer of approximately 10 Å to 20 Å, as shown by the cross hatched portion 58 of the magnetic layer 26.

A graphical representation of the implantation of carbon ions of various energy levels into a magnetic layer is presented in Fig. 3. More specifically, Fig. 3 depicts an implantation profile 70 for 10 eV carbon ions, wherein the vertical axis (I/I_0) represents the quantity of carbon ions and the horizontal axis represents the implantation depth of the carbon ions from the surface (zero) into the magnetic media layer which is composed of a CoPtCr alloy. In like manner, graphical profile 74 represents 50 eV carbon ions, graphical profile 78 represents 100 eV carbon ions and graphical profile 82 represents 500 eV carbon ions. As is seen in Fig. 3, the great majority of 10 eV carbon ions 70 are deposited within the first 5 Å, and nearly all of the 10 eV carbon ions are deposited within the first 8 Å of the magnetic layer. With regard to 100 eV carbon ions 78, a significant portion thereof are deposited in excess of 10 Å. Thus, the

crosshatched portion 58 of magnetic layer 26 of Fig. 2 may be generally as deep as 20 Å for the 100 eV carbon ions.

Significantly, the implanted carbon ions influence the magnetic properties of the magnetic layer portion 58 and degrade its performance. The degraded performance of the ion implanted upper portion 58 of the magnetic layer can be quite significant with regard to overall disk performance, because the upper portion 58 of the magnetic layer 26 contributes significantly to the performance characteristics of magnetic data bits that are written into the magnetic layer. Therefore, the high energy overcoat layer 54 is thinner than the prior art low energy magnetron sputtered layer 30, while still providing good hardness and corrosion resistance; but the magnetic performance properties of the hard disk 50 are somewhat degraded due to the implantation of carbon overcoat layer ions into the magnetic layer 26. The present invention provides an improvement in the prior art overcoat layer technologies by utilizing an ion deposition beam having an energy gradient, such that carbon ion implantation into the magnetic layer is minimized, while the desired thinness and density of the DLC overcoat layer are achieved.

As depicted in Fig. 4, a magnetic media hard disk 100 of the present invention generally includes the substrate 14, underlayer 18 and magnetic layer 26, as are generally known in the prior art and described hereabove with regard to Figs. 1 and 2 above, and a DLC overcoat layer 108 of the present invention that is fabricated on top of the magnetic layer 26. In that the present invention relates generally to the DLC overcoat layer 108, magnetic media hard disks having other, different and additional layers fabricated beneath the magnetic layer 26, as well as various magnetic layer compositions are intended to be included within the scope of the present invention.

As has been indicated above, the overcoat layer 108 of the present invention is thinner and denser than the low energy magnetron sputtered layer 30, and it is fabricated such that carbon ion implantation into the magnetic layer 26 is minimized. To accomplish this, the overcoat layer 108 is fabricated utilizing a device that produces an ion beam that has an ion deposition energy gradient. Specifically, the fabrication of the overcoat layer 108 is commenced with the deposition of an initial overcoat layer portion 112 with a low energy ion beam, such as a 10 to 20 eV ion beam, which is generally the energy level of the low energy magnetron sputtering process of the prior art, as depicted in Fig. 1. Thereafter, as the deposition of the initial overcoat layer portion 112 progresses, the overcoat layer 112 increases in thickness upon the surface of the magnetic layer 26, and due to the relatively low deposition beam energy level, implantation of overcoat layer ions into the magnetic layer 26 is minimized. After the initial overcoat layer thickness is deposited at the low energy level, the energy level of the beam is increased to deposit an intermediate overcoat layer portion 116. The higher energy ions will penetrate more deeply into the surface layer, as has been described hereabove with regard to prior art disk 50; however, because the initial surface layer 112 has been formed of overcoat material, the higher energy overcoat ions penetrate only into the pre-existing initial overcoat layer portion 112. Thus, as the build up of the intermediate overcoat layer portion 116 progresses, the total overcoat layer generally both becomes thicker with overcoat ions that remain on its surface, as well as denser with higher energy overcoat ions that become implanted within the thickness of the initial overcoat layer. Thereafter, a subsequent overcoat layer portion 118 may be deposited with a still higher ion beam energy level. Again, these higher energy overcoat ions penetrate into the surface of the overcoat layer 108. However, due to the thickness of the existing overcoat layer the high energy ions become implanted into both the initial and

intermediate overcoat layer portions and do not penetrate into the magnetic layer 26. A typical DLC overcoat layer density of the present invention is between approximately 2.0 g/cm³ to approximately 2.9 g/cm³.

Fig. 5 is a graphical representation of 100 eV carbon ion implantation into a magnetic disk having surface layers deposited thereon. Specifically, the graphical profile 120 represents the implantation of 100 eV carbon ions into a CoPtCr magnetic layer having no surface layer deposited thereon, and it can be seen that profile 120 is substantially identical to profile 78 of Fig. 3. Profile 124 represents the 100 eV carbon ion implantation into a 20 Å aC:H surface layer having a density of 1.7 grams/centimeter. It can be seen that the great majority of the 100 eV carbon ions are deposited within the 20 Å depth of the surface layer. Graphical profile 128 represents the implantation of 100 eV carbon ions into a 20 Å IBD-C surface layer having a density of 2.2 grams/centimeter, wherein it is seen that nearly all of the 100 eV carbon ions are implanted within the 20 Å IBD-C surface layer. It is therefore to be understood from the graphical representations of Fig. 5 that a sufficiently dense surface layer will prevent the implantation of 100 eV carbon ions into the magnetic layer of a hard disk.

It is therefore to be generally understood that the energy gradient of the ion beam is to be controlled in association with the thickness of the overcoat layer that is being fabricated, such that the highest beam energy levels are utilized when the thickness of the overcoat layer is close to its desired thickness. In this ion beam energy gradient fabrication process the higher energy ions become predominantly implanted into the pre-existing overcoat layer portion, thereby increasing its density, hardness and corrosion resistance, without adding significantly to its thickness, and implantation of ions into the magnetic layer is minimized. Additionally, it is known that the addition of nitrogen ions into the DLC layer can have a positive effect upon its

hardness and corrosion resistance. However, nitrogen ions can also create significant problems if they become implanted into the magnetic layer. Therefore, in an alternative preferred embodiment of the present invention, the initial lower energy overcoat layer fabrication is conducted without nitrogen ions. Thereafter, when an initial low energy overcoat layer has been deposited, nitrogen ions are then included within the higher energy ion beam, to also become implanted within the overcoat layer, rather than into the magnetic layer. A nitrogen enhanced DLC layer is thereby produced in which nitrogen ion implantation into the magnetic layer is minimized.

The present invention has been implemented in a Circulus magnetic media hard disk fabrication device. In this device, the DLC overcoat layer is applied onto the magnetic layer of hard disks utilizing a radio frequency (RF) discharge chamber, which creates an overcoat ion plasma from a gaseous source. In this device, a deposition rate of approximately 10 Å per second is achieved with appropriate input gas concentrations and other control parameters as are well known to those skilled in the art.

To create a DLC overcoat layer of the present invention, acetylene gas was utilized as the carbon ion source. The chamber control parameters were set such that the acetylene gas produced a carbon ion plasma that was directed to the magnetic layer of a hard disk disposed within the chamber. The disk was exposed to an ion beam energy of approximately 10 eV for approximately one second, resulting in an initial carbon overcoat layer having a thickness of approximately 10 Å. Thereafter, the ion beam energy level was increased to approximately 50 eV and the disk was exposed for an additional one second to add an intermediate overcoat layer portion 116, to create an overcoat layer having a thickness of approximately 19 Å. Thereafter, the ion beam energy was increased to approximately 100 eV, and the disk was exposed to the ion

beam for approximately one second, to produce a subsequent overcoat layer portion 118, such that the total overcoat layer 108 has a thickness of approximately 25 Å. In an enhanced overcoat layer deposition process, nitrogen gas can be mixed with the acetylene gas in the second and third deposition energy level steps to create nitrogen ions that are implanted into the overcoat layer. The concentration of nitrogen can be increased as the energy level is increased to create a nitrogen enhanced overcoat layer. A preferred concentration range of nitrogen ions within the overcoat layer is from approximately 2 at. % to approximately 20 at. %.

While the example provided hereabove demonstrates the use of a three step (10 eV, 50 eV, 100 eV) ion beam energy gradient, it is to be understood that the present invention can be practiced utilizing a two step gradient, a multiple step gradient, and a smooth energy gradient. Additionally, ion beam energy levels in excess of 100 eV are contemplated, although there appears to be little advantage to ion beam energy levels in excess of approximately 100 eV. A general principal of the present invention is that the thickness of the DLC layer formed at lower energy levels be sufficient to capture the carbon and nitrogen ions that become implanted at higher energy levels. With the use of appropriate process parameters such as deposition rates and times, as will be understood by those skilled in the art after having read this disclosure, the thickness and density of the overcoat layer can be controlled. Preferred embodiments of the present invention have an overcoat thickness of from approximately 25 Å to approximately 100 Å, with a more preferred upper thickness range of approximately 60 Å, and with a more preferred thickness of approximately 35 Å; the density of the overcoat is between approximately 2.0 g/cm³ to 2.9 g/cm³, and the optional nitrogen concentration is from 2 at. % to 20 at. %

The magnetic disk of the present invention is designed for installation in a hard disk drive, and Fig. 6 is a schematic top plan view of a hard disk drive 200 which includes at least

one, and typically a plurality, of magnetic disks 100 of the present invention. As depicted therein, at least one magnetic head disk 100 is rotatably mounted upon a motorized spindle 204. A slider 208, having a magnetic head 212 disposed thereon, is mounted upon an actuator arm 216 to fly above the surface of each rotating hard disk 100, as is well known to those skilled in the art. The hard disk drive 200 of the present invention thus includes improved features and manufacturing methods for the magnetic disk 100 as have been described hereabove.

While the present invention has been shown and described with reference to certain preferred embodiments, it is to be understood that those skilled in the art will no doubt devise certain alterations and modifications thereto which nevertheless include the true spirit and scope of the present invention. It is therefore intended that the following claims cover all such alterations and modifications in form and detail that nevertheless include the true spirit and scope of the present invention.

What we claim is:

CLAIMS

1 1. A magnetic media hard disk, comprising:
2 a substrate;
3 a magnetic layer;
4 at least one underlayer being disposed between said substrate and said magnetic layer;
5 an overcoat layer being disposed above said magnetic layer, said overcoat layer being
6 comprised of diamond-like carbon (DLC), and wherein carbon atoms of said DLC layer are
7 generally implanted into said magnetic layer to a depth of less than approximately 10 Å, and
8 wherein the density of said overcoat layer is between approximately 2.0 g/cm³ and
9 approximately 2.9 g/cm³.

1 2. A magnetic disk as described in claim 1 wherein the thickness of said overcoat layer is
2 from approximately 25 Å to approximately 100 Å.

1 3. A magnetic disk as described in claim 1 wherein the thickness of said overcoat layer is
2 from approximately 25 Å to approximately 60 Å.

1 4. A magnetic disk as described in claim 1 wherein the thickness of said overcoat layer is
2 approximately 35 Å.

1 5. A magnetic disk as described in claim 1 wherein said overcoat layer includes nitrogen.

6. A magnetic disk as described in claim 5 wherein said overcoat layer includes nitrogen in the range of approximately 2 at. % to approximately 20 at. %.

7. A hard disk drive, comprising:

at least one magnetic media hard disk being adapted for rotary motion upon a disk drive motor spindle;

at least one slider device having a slider body portion being adapted to fly over said magnetic media hard disk;

a magnetic head being formed on said slider body for writing data to said magnetic media hard disk and reading data from said magnetic media hard disk;

said magnetic media hard disk, including:

a substrate;

a magnetic layer;

at least one underlayer being disposed between said substrate and said magnetic layer;

an overcoat layer being disposed above said magnetic layer, said overcoat layer being comprised of diamond-like carbon (DLC), and wherein carbon atoms of said DLC layer are generally implanted into said magnetic layer to a depth of less than approximately 10 Å, and wherein the density of said overcoat layer is between approximately 2.0 g/cm³ and approximately 2.9 g/cm³.

8. A hard disk drive as described in claim 7 wherein the thickness of said overcoat layer is from approximately 25 Å to approximately 100 Å.

1 9. A hard disk drive as described in claim 7 wherein the thickness of said overcoat layer is
2 from approximately 25 Å to approximately 60 Å.

1 10. A hard disk drive as described in claim 7 wherein the thickness of said overcoat layer is
2 approximately 35 Å.

1 11. A hard disk drive as described in claim 7 wherein said overcoat layer includes nitrogen.

1 12. A hard disk drive as described in claim 11 wherein said overcoat layer includes nitrogen
2 in the range of approximately 2 at. % to approximately 20 at. %.

1 13. A process for fabricating a magnetic media hard disk comprising the steps of:
2 fabricating a magnetic media layer upon a surface material of a substrate;
3 fabricating a diamond-like carbon (DLC) layer upon said magnetic layer, including the
4 steps of:

5 fabricating an initial thickness DLC layer portion upon said magnetic layer
6 utilizing a relatively low ion carbon beam energy;

7 fabricating a subsequent thickness DLC layer portion upon said initial thickness
8 DLC layer portion utilizing a relatively high carbon ion beam energy.

1 14. A process for fabricating a magnetic media hard disk as described in claim 13 wherein
2 said relatively low carbon ion beam energy is approximately 10 eV to approximately 20 eV.

1 15. A process for fabricating a magnetic media hard disk as described in claim 14 wherein
2 said relatively high ion beam energy is approximately 100 eV.

1 16. A process for fabricating a magnetic media hard disk as described in claim 13, including
2 the further step of fabricating an intermediate thickness DLC layer portion between said initial
3 DLC layer portion and said subsequent DLC layer portion, wherein said intermediate thickness
4 DLC layer portion is fabricated utilizing a relatively mid-range carbon ion beam energy between
5 said relatively low carbon ion beam energy and said relatively high carbon ion beam energy.

1 17. A process for fabricating a magnetic media hard disk as described in claim 16 wherein
2 said intermediate carbon ion beam energy is approximately 50 eV.

1 18. A process for fabricating a magnetic media hard disk as described in claim 17 wherein
2 said DLC layer has a thickness of approximately 10 Å following the deposition of said initial
3 thickness DLC layer portion, and said DLC layer has a thickness of approximately 19 Å
4 following the deposition of said intermediate thickness DLC layer portion, and said DLC layer
5 has a final thickness of approximately 25 Å following the deposition of said subsequent
6 thickness DLC layer portion.

1 19. A method for fabricating a magnetic media hard disk as described in claim 18 wherein
2 said DLC layer is formed with a density of approximately 2.0 g/cm³ to approximately 2.9 g/cm³.

1 20. A method for fabricating a magnetic media hard disk as described in claim 13 wherein
2 nitrogen ion species are deposited within said subsequent thickness DLC layer portion.

1 21. A process for fabricating a magnetic media hard disk as described in claim 20 wherein
2 said nitrogen species are deposited in a range of approximately 2 at. % to approximately 20 at.
3 %.

1 22. A method for fabricating a magnetic media hard disk comprising the steps of:
2 fabricating a magnetic material layer upon a material surface of a substrate;
3 fabricating a diamond-like carbon (DLC) layer upon said magnetic layer, wherein said
4 DLC layer is fabricated in the steps of:
5 depositing carbon ion species upon said magnetic layer utilizing a relatively low
6 carbon ion beam energy of from approximately 10 eV to approximately 20 eV, to deposit an
7 initial DLC layer thickness;
8 subsequently increasing the carbon ion beam energy level as the thickness of said
9 DLC layer increases due to deposition of carbon ion species within said DLC layer, such that
10 higher energy carbon ion beam species become implanted within said DLC layer thickness.

1 23. A method for fabricating a magnetic media disk as described in claim 22 wherein said
2 carbon ion beam energy level is varied smoothly with time.

1 24. A method for fabricating a magnetic media hard disk as described in claim 22 wherein
2 said carbon ion beam energy level varies as a step function with time.

1 25. A method for fabricating a magnetic media hard disk as described in claim 23 wherein
2 nitrogen ion species are implanted within said DLC layer thickness.

1 26. A method for fabricating a magnetic media hard disk as described in claim 25 wherein
2 said nitrogen ion species are included within said DLC layer in a range of approximately 2 at. %
3 to approximately 20 at. %.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183
2184
2185
2186
2187
2188
2189
2190
2191
2192
2193
2194
2195
2196
2197
2198
2199
2200
2201
2202
2203
2204
2205
2206
2207
2208
2209
2210
2211
2212
2213
2214
2215
2216
2217
2218

ABSTRACT

ENERGY GRADIENT ION BEAM DEPOSITION OF CARBON OVERCOATS ON RIGID DISK MEDIA FOR MAGNETIC RECORDINGS

In the energy gradient ion beam deposition technique of the present invention, the
5 fabrication of the overcoat layer starts with a low energy ion beam to avoid magnetic layer
implantation problems, followed by higher deposition energies where the higher energy atoms
are implanted into the previously formed lower energy overcoat layer, rather than the magnetic
layer. The energy gradient ion beam deposition process therefore results in a thin overcoat layer
that is denser than a comparable layer formed by low energy magnetron sputtering, and which
10 overcoat layer provides good mechanical and corrosion protection to the magnetic layer, without
degrading the magnetic properties of the magnetic layer. Where a magnetic media hard disk of
the present invention is utilized within a hard disk drive, the thinner overcoat layer allows the
magnetic head of the disk drive to fly closer to the magnetic media layer, thereby facilitating an
15 increase in the areal data storage density of the hard disk drive.

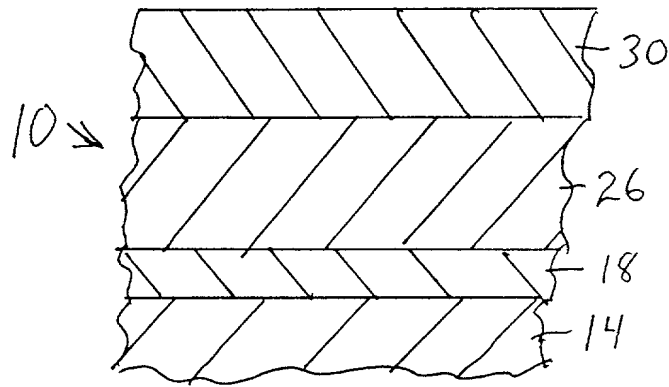


FIG. 1

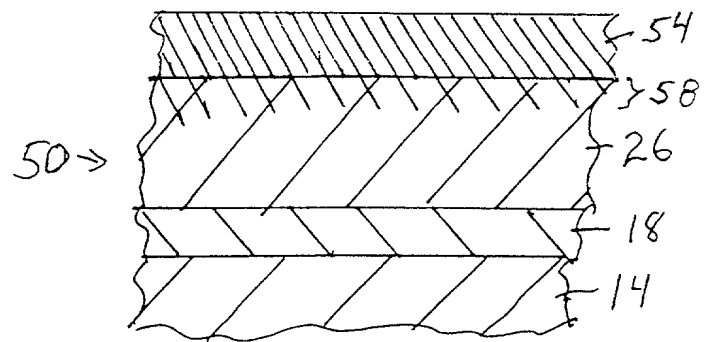


FIG. 2

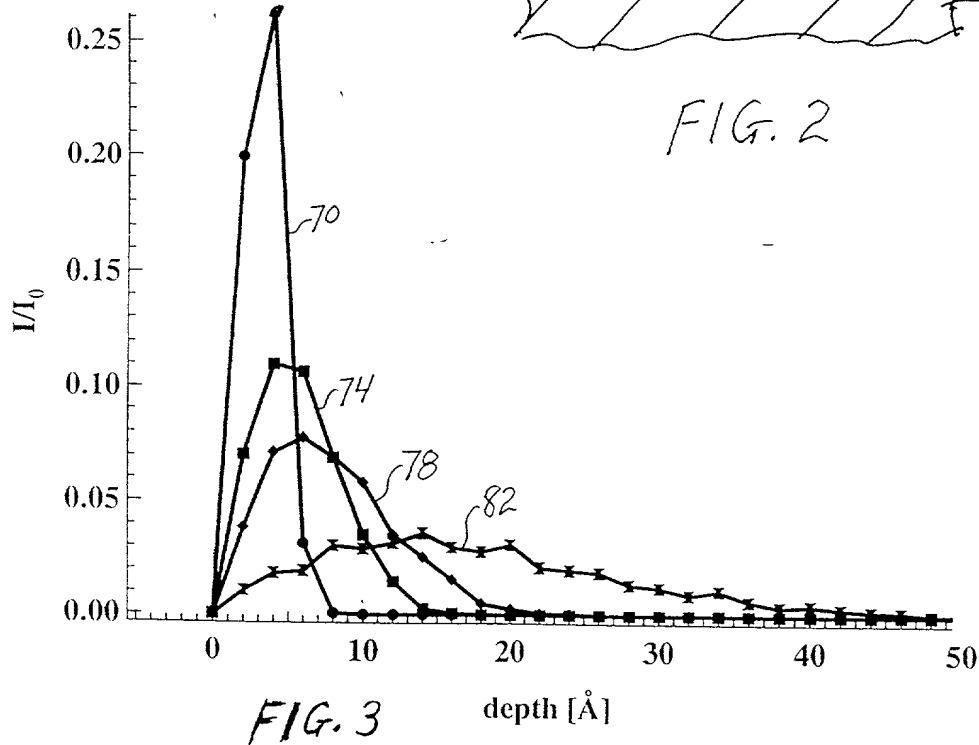


FIG. 3

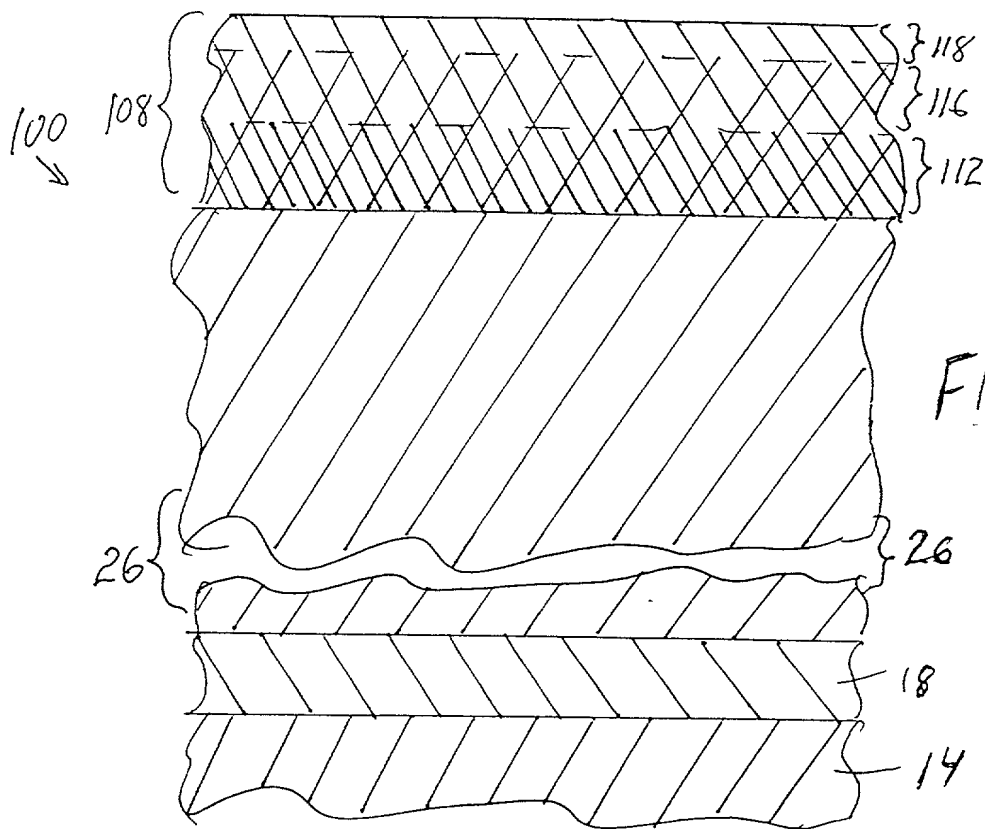


FIG. 4

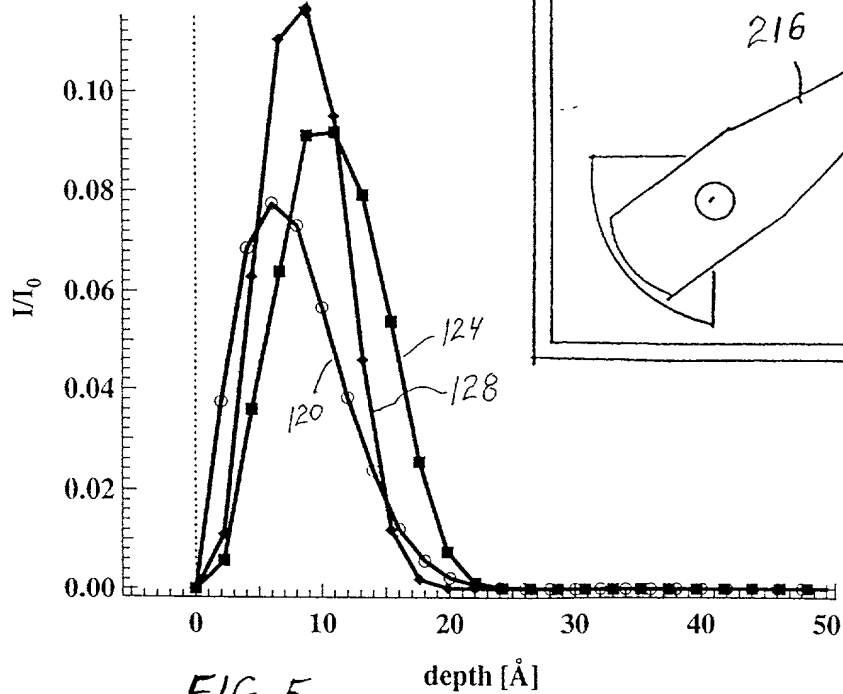


FIG. 5

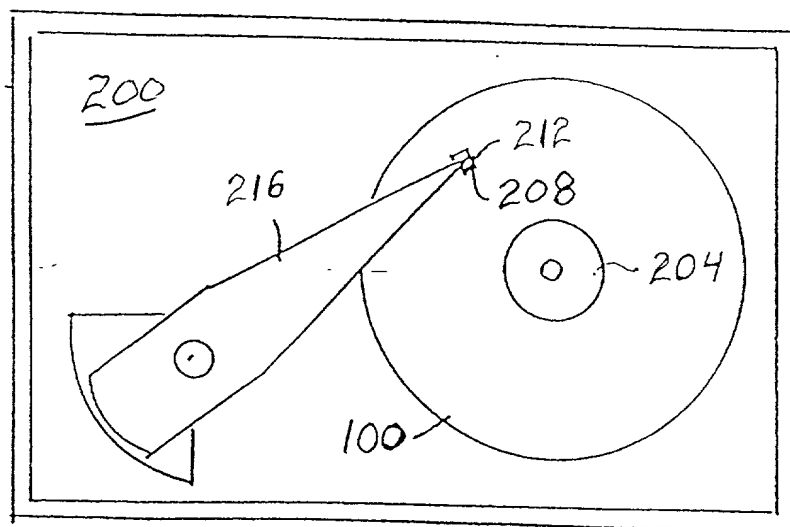


FIG. 6

DECLARATION, POWER OF ATTORNEY AND PETITION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **"Energy Gradient Ion Beam Deposition of Carbon Overcoats on Rigid Disk Media for Magnetic Recordings"** the specification of which

(check one) ☒ is attached hereto.
☐ was filed on _____ as Application Serial No. _____
 and was amended on _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, § 1.56(a).

I hereby claim foreign priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application of which priority is claimed.

Prior Foreign Application(s)

Priority Claimed

	Yes	No
(Number)(Country)(Day, month, year filed)	Yes	No
(Number)(Country)(Day, month, year filed)	Yes	No
(Number)(Country)(Day, month, year filed)	Yes	No

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, § 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial No.)	Filing Date	(Status: Patented, pending, abandoned)
(Application Serial No.)	Filing Date	(Status: Patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

And I hereby appoint W. POMS, REG. 18,782; G.P. SMITH, REG. 20,142; G. E. LANDE, REG. 22,222; A.C. ROSE, REG. 17,047; L.J. BOVASSO, REG. 24,075; C. BERMAN, REG. 29,249; D.J. OLDENKAMP, REG. 29,421; C. DARROW, REG. 30,166; M.E. HARRIS, REG. 26,690; K.A. MACLEAN, REG. 31,118; C. ROSENBERG, REG. 31,464; M.E. BROWN, REG. 28,590; S.R. HANSEN, REG. 38,486; D.N. LARSON, REG. 29,401; J.W. INSKEEP, REG. 33,910; H.D. JASTRAM, REG. 19,777; B. CANTER, REG. 34,792; C.J. LERVICK, REG. 35,244; L. CULLMAN, REG. 39,645; C.A.S. HAMRICK, REG. 22,586; R.O. GUILLOT, REG. 28,852; J. BOYCE, REG. 40,920; C. CHOU, REG. 41,672; A.B. DIEPENBROCK, REG. 39,960; M.K. BOSWORTH, REG. 28,186; L. SHERRY, REG. 43,918; L. McROSS, REG. 40,427; E.E. KLEIN, REG. 34,337;

P. SABER, REG. 37,494; E.A. PENNINGTON, REG. 32,588; J.C. REDMOND, JR., REG. 18,753; R.B. MARTIN, REG. 26,945; R.J. BLUESTONE, REG. 40,518; D.R. MILLETT, REG. 31,784; C.A. HUGHES, REG. 26,914; J.E. HOEL, REG. 26,279; OPPENHEIMER WOLFF & DONNELLY LLP, 1400 Page Mill Road, Palo Alto, California 94304, (650) 320-4000, as my attorneys with full power of substitution and revocation, to prosecute said application and to transact in connection therewith all business in the Patent and Trademark Office and before competent International Authorities.

Address all telephone calls to Robert O. Guillot at (650) 320-4000, and address all correspondence to:

Robert O. Guillot, Esq.
OPPENHEIMER WOLFF & DONNELLY LLP
 1400 Page Mill Road
 Palo Alto, CA 94304

Wherefore I pray that Letters Patent be granted to me for the invention or discovery described and claimed in the foregoing specification and claims, and I hereby subscribe my name to the foregoing specification and claims, declaration, power of attorney, and this petition.

Full Name of Sole or First Inventor: Daryl J. Pocker

Home Address: 1123 Petroni Way, San Jose, CA 95120

Post Office Address: Same as above

Citizenship: United States

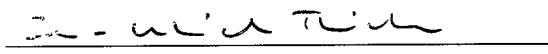
Inventor's Signature:  Date: Nov. 16, 2000

Full Name of Second Inventor: Jan-Ulrich Thiele

Home Address: 806 Coleman Avenue #5, Menlo Park, CA 94025

Post Office Address: Same as above

Citizenship: Germany

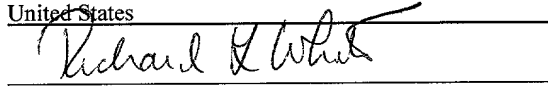
Inventor's Signature:  Date: Nov. 17, 2000

Full Name of Third Inventor: Richard L. White

Home Address: 928 Clinton Road, Los Altos, CA 94024

Post Office Address: Same as above

Citizenship: United States

Inventor's Signature:  Date: Nov 16, 2000

Full Name of Fourth Inventor: Bing K. Yen

Home Address: 5583 Blossom Garden Circle, San Jose, CA 95123

Post Office Address: Same as above

Citizenship: United States

Inventor's Signature: B. K. Yen Date: Nov. 17, 2000